DOCUMENT RESUME

ED 057 333 AC 012 188

AUTHOR	Taylor, Elaine N.; Vineberg, Robert
TITLE	Marginal Manpower: Job Capability as a Joint Function of Aptitude and Experience.
INSTITUTION	Human Resources Research Organization, Alexandria, Va.
SPONS AGENCY	Office of the Chief of Research and Development (Army), Washington, D.C.
REPORT NO	HumRRO-PP-18-71
PUB DATE	Aug 71
NOTE	24p.; Paper presented at Military Operations Research Symposium (26th, Monterey, Calif., November 1970)
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Aptitude; Comparative Analysis; Cooks; Data Analysis; Job Analysis; Maintenance; *Manpower Development; *Military Personnel; Performance Specifications; Supplies; *Task Performance; Tests; *Work Experience
IDENTIFIERS	United States Army

ABSTRACT

The job performance of men in four different occupational specialties (Vehicle Repairman, Supply Clerk, Armor Crewman, and Cook) was measured by intensive Job Sample Tests of 4 to 5 hours in length and by more conventional Job Knowledge Tests. Curves have been derived that provide estimates of how job performance can be expected to vary as a function of an incombent's aptitude level and amount of job experience. As measured by Job Sample Tests, the performance of men at all levels of aptitude increases with job experience out to approximately five years on the job. During this time, separation between different aptitude groups is generally maintained. Beyond five years, performance of the different groups tends to converge. Scatter plots of these data are used to identify an empirically based, operational definition of job proficiency. (Author)

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Professional
Paper
18-71

ED057333

Marginal Manpower: Job Capability as a Joint Function of Aptitude and Experience

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Presentation at
26th Military Operations Research Symposium
Monterey, California November 1970

August
1971

HC012188

Prepared for

Office of the Chief of Research and Development
Department of the Army
Washington, D.C. 20310

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Published
August 1971
by
HUMAN RESOURCES RESEARCH ORGANIZATION
300 North Washington Street
Alexandria, Virginia 22314

BIBLIOGRAPHIC DATA SHEET	1. Report No. HumRRO-PP-18-71	2.	3. Recipient's Accession No.
4. Title and Subtitle Marginal Manpower: Job Capability as a Joint Function of Aptitude and Experience			5. Report Date August 1971 6.
7. Author(s) Elaine N. Taylor and Robert Vineberg			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Human Resources Research Organization (HumRRO) 300 North Washington Street Alexandria, Virginia 22314			10. Project/Task/Work Unit No. UTILITY 12-35 11. Contract/Grant No. DAHC 19-70-C-0012
12. Sponsoring Organization Name and Address Office, Chief of Research and Development Department of the Army Washington, D.C. 20310			13. Type of Report & Period Covered Professional Paper 18-71 14.
15. Supplementary Notes HumRRO Division No. 3, Presidio of Monterey, California; presented at 26th Military Operations Research Symposium, Monterey, Calif.; November 1970.			

16. Abstracts

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17. Key Words and Document Analysis. 17a. Descriptors

*Army training
*Performance evaluation
*Abilities
*Aptitudes

17b. Identifiers/Open-Ended Terms

Armed Forces Qualification Test scores
Category IV soldiers

17c. COSATI Field/Group 0509 Behavioral and social sciences
Personnel selection, training, and evaluation

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Approved for public release; distribution unlimited.	UNCLASSIFIED	22
	20. Security Class (This Page) UNCLASSIFIED	22. Price

FORM NTIS-35 (10-70) USCOMM-DC 40329-P71

Prefatory Note

This paper, presented at the MORS symposium by Dr. Taylor, concerns some of the data from a large-scale research project done by the Human Resources Research Organization, Division No. 3, Presidio of Monterey, California. Dr. Taylor is a Senior Scientist and Dr. Vineberg, a Senior Staff Scientist at the HumRRO Division. The research was performed under Work Unit UTILITY, Study of Soldiers in Lower Mental Categories: Job Performance and the Identification of Potentially Successful and Potentially Unsuccessful Men.

The authors were assisted by Mr. Edward Kingsley, HumRRO Division No. 1, and Dr. Eugene A. Cogan, HumRRO Director for Research Design and Reporting, in the mathematical derivation of the prediction equations used in this paper and in the preparation of the material reported.

MARGINAL MANPOWER: JOB CAPABILITY AS A JOINT FUNCTION OF APTITUDE AND EXPERIENCE

Elaine N. Taylor and Robert Vineberg

INTRODUCTION

The problem of performance and acceptability of the lower aptitude man in the military, what he can do and what he can't do, is a continuing one. While experience (e.g., in times of national mobilization) has provided ample evidence that many men with low aptitude test scores can perform effectively, there has been no systematic information gathered about how well they really do.

The data that will be discussed were collected as part of an extensive HumRRO study—Work Unit UTILITY, Study of Men in Lower Mental Categories: Job Performance and the Identification of Potentially Successful and Potentially Unsuccessful Men—undertaken to provide such information.[1] The research was designed to compare the job performance of men of different ability levels and to map the manner in which their performance changes as a function of the length of time they have been in their jobs. Because of the evidence that many low aptitude men do perform effectively, the study also attempted to identify those personal and background characteristics that might distinguish the more effective marginal individuals.

Data bearing only on our first objective—the mapping of performance as a function of Armed Forces Qualification Test (AFQT) score and job experience—will be considered. The AFQT is the instrument used throughout the Armed Forces to measure a man's general aptitude for military service. Every man entering the service is classified into one of the five mental groups on the basis of his AFQT score.

Mental Group	AFQT or Percentile Score
I	93-100
II	65- 92
III	31- 64
IV	10- 30
V	0- 9

Men whose scores place them in Groups IV and V are considered marginal and their acceptance into the military is dependent upon the minimum standard prevailing at that particular time. We will refer to this marginal group simply as Group IV or Category IV herein.

We studied men who were Armor Crewmen, Vehicle Repairmen, Supply Clerks, and Cooks. In addition to choosing Army jobs that were highly populated, and particularly those with a fair proportion of low aptitude men, we selected these four jobs because they covered a fairly broad range of job types and task complexity, and because, with the exception of the Armor Crewman, each had a civilian counterpart.

The Armor Crewman's job may be considered machine-ascendant in that it consists principally of sequences of interaction between a man and a tank and its weapon systems, with most tasks being largely procedural. The Repairman is a maintenance job

[1] There is a list of publications from this effort and related research on the last page of this paper.

that requires diagnostic and interpretive skills. The Supply Clerk's job is, of course, clerical, calling primarily for the coordination and recording of information. The Cook prepares food in accordance with a master menu and detailed recipes. Recognition of standards and precision in meeting them are primary characteristics of this job.

Job incumbents were tested in combat divisions in the United States and in Germany. Within each division we selected pairs of men for testing. Each pair included one man in Mental Category IV, with an AFQT or percentile score between one and 30, and one man in Mental Categories I-III, with an AFQT score between 31 and 99. Pair members were carefully matched for the amount of time they had been in their jobs. In each job, some pairs of men were studied who had up to 20 years of job experience. Particular care was taken, in preliminary visits to units, to insure that all men in the sample were working on a continuous daily basis in their jobs. A total of approximately 1600 men were tested, or 195 pairs, in each job.

We measured performance using job sample tests, conventional multiple choice job knowledge tests, and supervisor ratings. As is frequently the case, supervisor ratings failed to be very discriminating.

Our primary criteria were the job sample tests. To our knowledge this is the only study that has undertaken such extensive and direct measurement of performance. Depending on the job, each individually administered job sample test took from 3½ to 5 hours to complete.

Each job sample test was comprised of a number of subtests. To make testing realistic and to simulate job conditions with as much fidelity as possible, each subtest consisted of the performance of a single entire task with a natural beginning and ending. Tasks were composed of a series of actions or steps that would ordinarily be performed as part of the actual performance of a job.

Subtest tasks or problems were introduced to men just at they might ordinarily encounter them. For example, one of the Repairman tasks involved the diagnosis and

General Vehicle Repairman's Test--Unbolting Fan Assembly

Figure 1

correction of a leaking oil seal in the fan shaft of a tank. The tank had been prepared so that the oil seals were leaking and the man was told that oil was being thrown out of the tank's grill doors. The Repairman was to locate the source of the oil leak and repair the malfunction. Figure 1 shows a man unbolting the fan assembly near the beginning of the problem.

In this problem, there were 19 necessary steps and a point was earned for the correct performance of each step. This scoring procedure was used throughout the testing. While we will not present detailed lists of all four job sample tests, the 13 subtests administered to Repairmen are shown as an example of the job sample instruments.

Table 1

Repairman's Test

SUBTEST	NUMBER OF STEPS
SHIFT LINKAGE ADJUSTMENT, M60A1 TANK	11
TRANSMISSION SERVO BAND ADJUSTMENT, M60A1 TANK	13
VOLTAGE REGULATOR ADJUSTING RHEOSTAT ADJUSTMENT, M60A1 TANK	17
HYDRAULIC BRAKE PEDAL ADJUSTMENT, M60A1 TANK	11
OIL SEAL MALFUNCTION IN COOLING FAN VERTICAL DRIVE SHAFT, DETECTION AND REPLACEMENT, M60A1 TANK	19
IGNITION MALFUNCTION, FAULTY SPARK PLUG, DETECTION, M151 JEEP	9
IGNITION TIMING, CHECK AND ADJUSTMENT, M151 JEEP	19
CYLINDER COMPRESSION CHECK, M151 JEEP	13
BATTERY HYDROMETER TEST, M151 JEEP	11
BATTERY CONDITION TEST, M151 JEEP	13
WHEELBEARING, MALFUNCTION, DETECTION AND ADJUSTMENT, M151 JEEP	13
FUEL PUMP PRESSURE CHECK, M35A1/A2, M49C TRUCK	10
BLEEDING SERVICE BRAKE SYSTEM, M35A1/A2, M49C TRUCK	17
	176

PERFORMANCE AS A FUNCTION OF AFQT AND JOB EXPERIENCE

Let us consider the data. First, the Figures show mean scores plotted by time, then scatter plots of individual scores, and finally, curves that have been fitted to the data; this latter set of curves will be related to levels of acceptable performance. Figures 2 through 5 show the performance of men in the Category IV and Categories I-III groups for each of the four jobs. Job sample performance is plotted at 1-9 months on the job, 10-24 months, 25-60 months, and more than 60 months. Figure 2 shows results for Armor Crewman. For both of the AFQT levels, scores go up with time in the job. While performance increases in both AFQT groups with time, the groups maintain their positions relative to each other seemingly getting somewhat closer beyond five years. For the group with more than five years on the job, men are averaging about 82% on the

Job Sample Test Score by AFQT and Months on Job: Armor Crewman

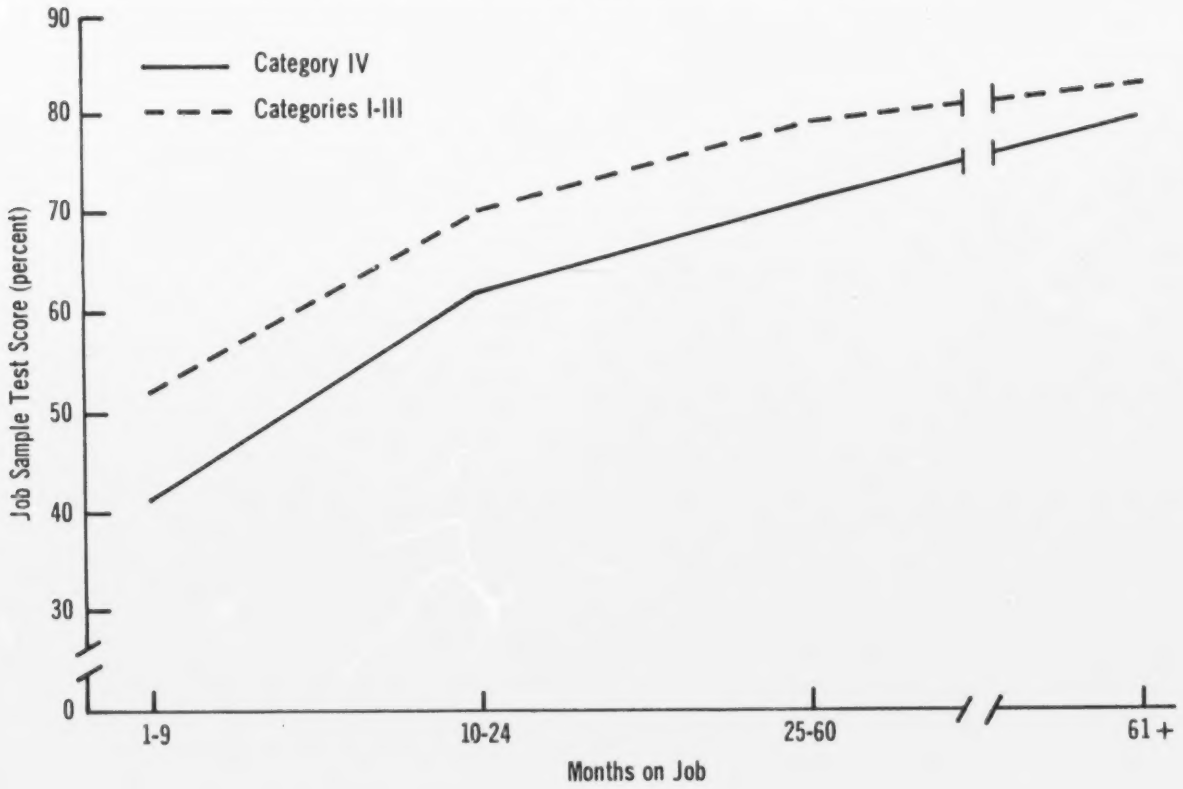

Figure 2

Job Sample Test Score by AFQT and Months on Job: Cook

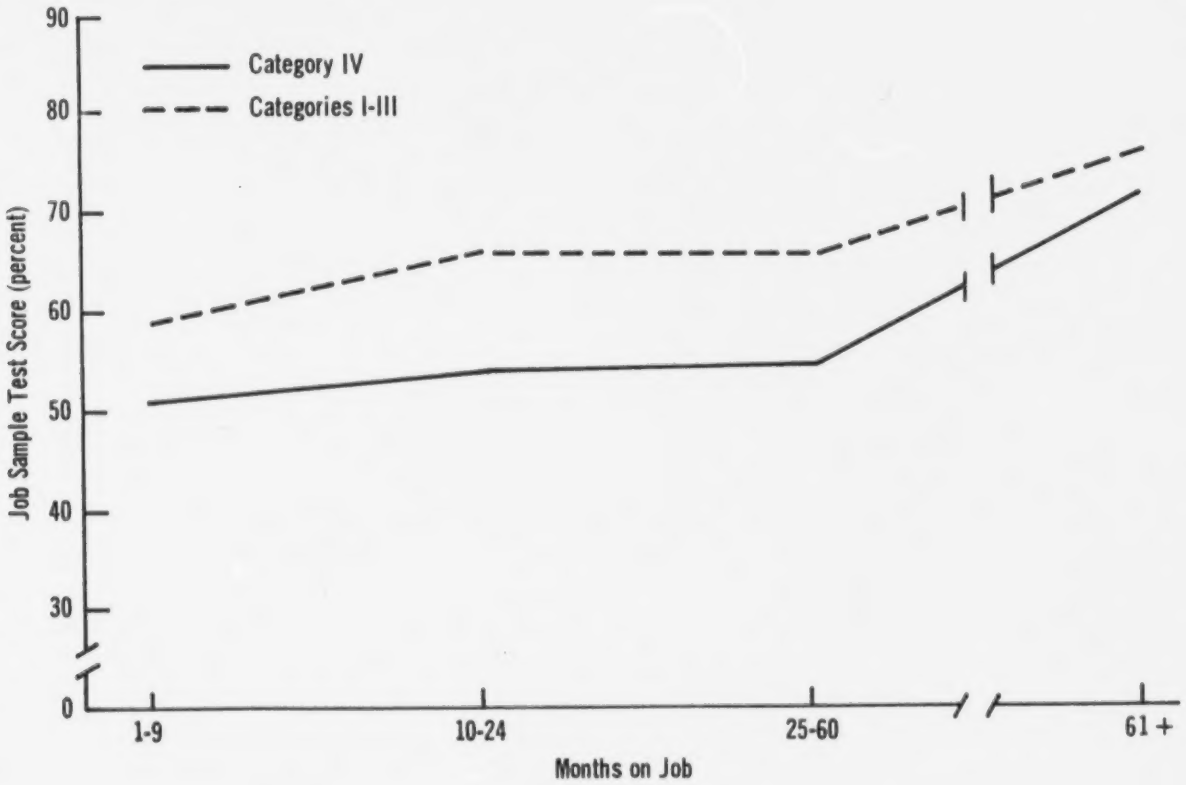

Figure 3

Job Sample Test Score by AFQT and Months on Job: Repairman

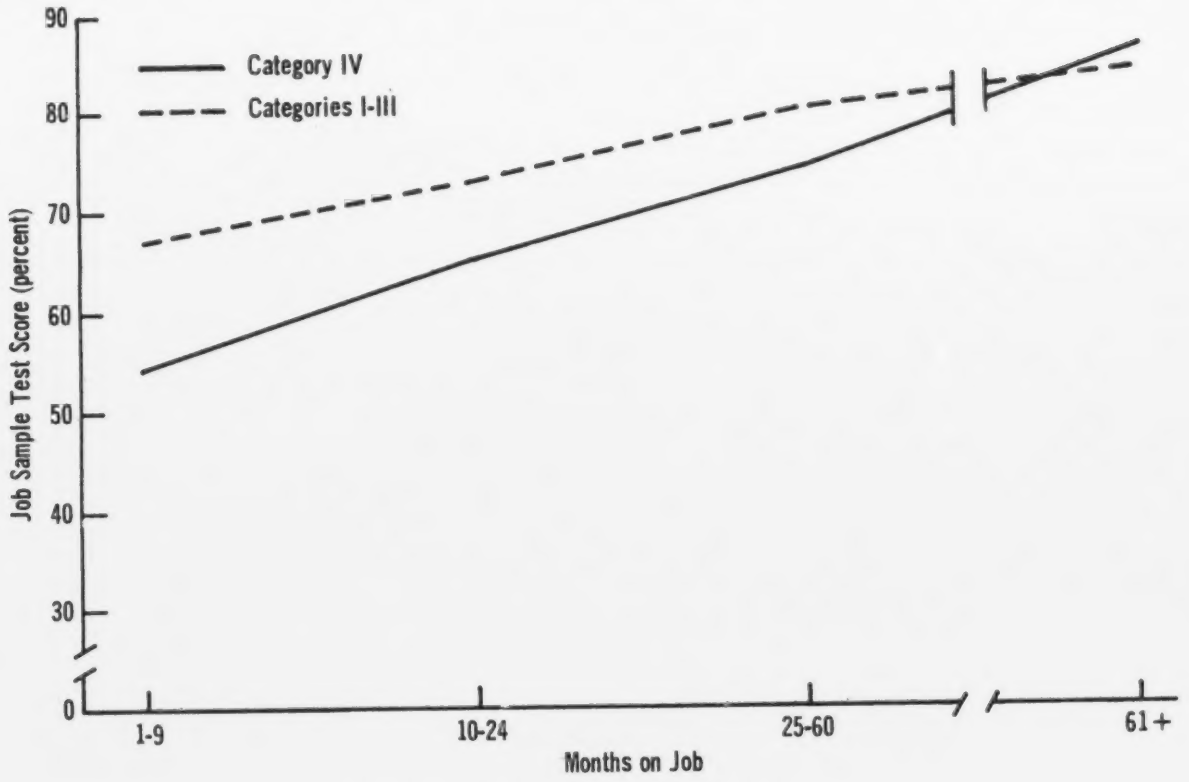

Figure 4

Job Sample Test Score by AFQT and Months on Job: Supply Specialist

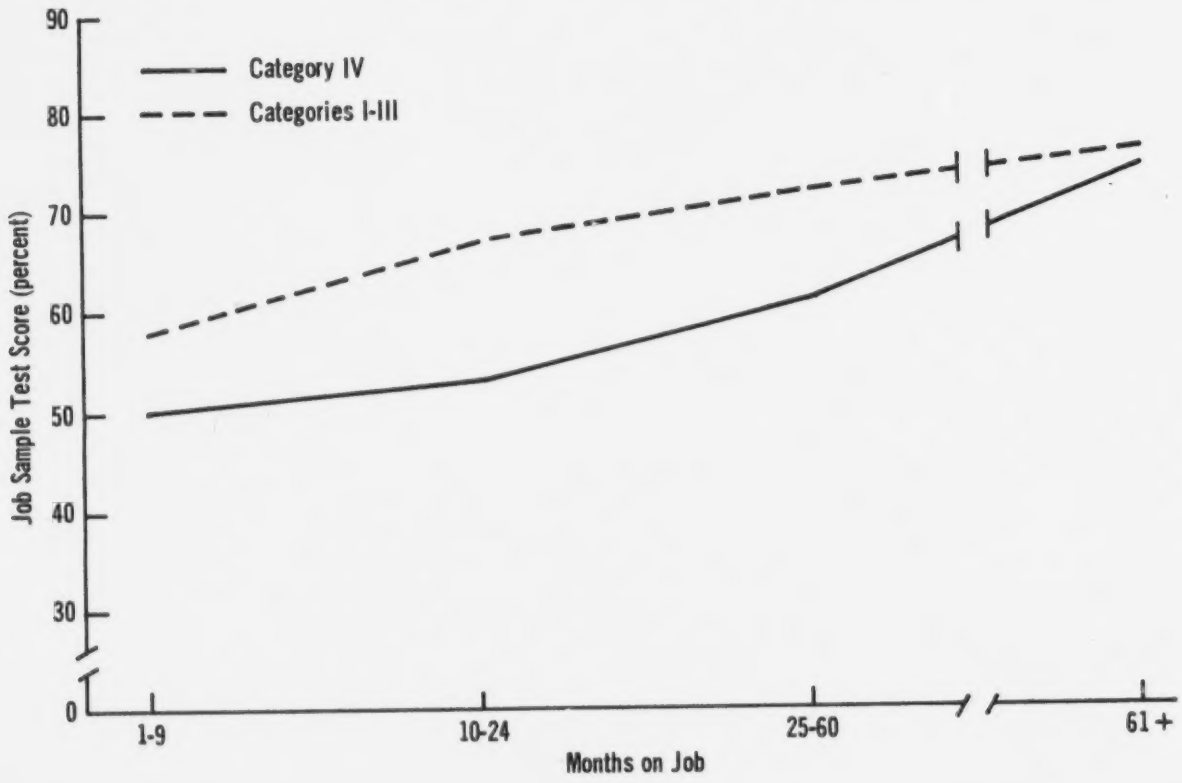

Figure 5

Job Knowledge Test Score by AFQT and Months on Job: Armor Crewman

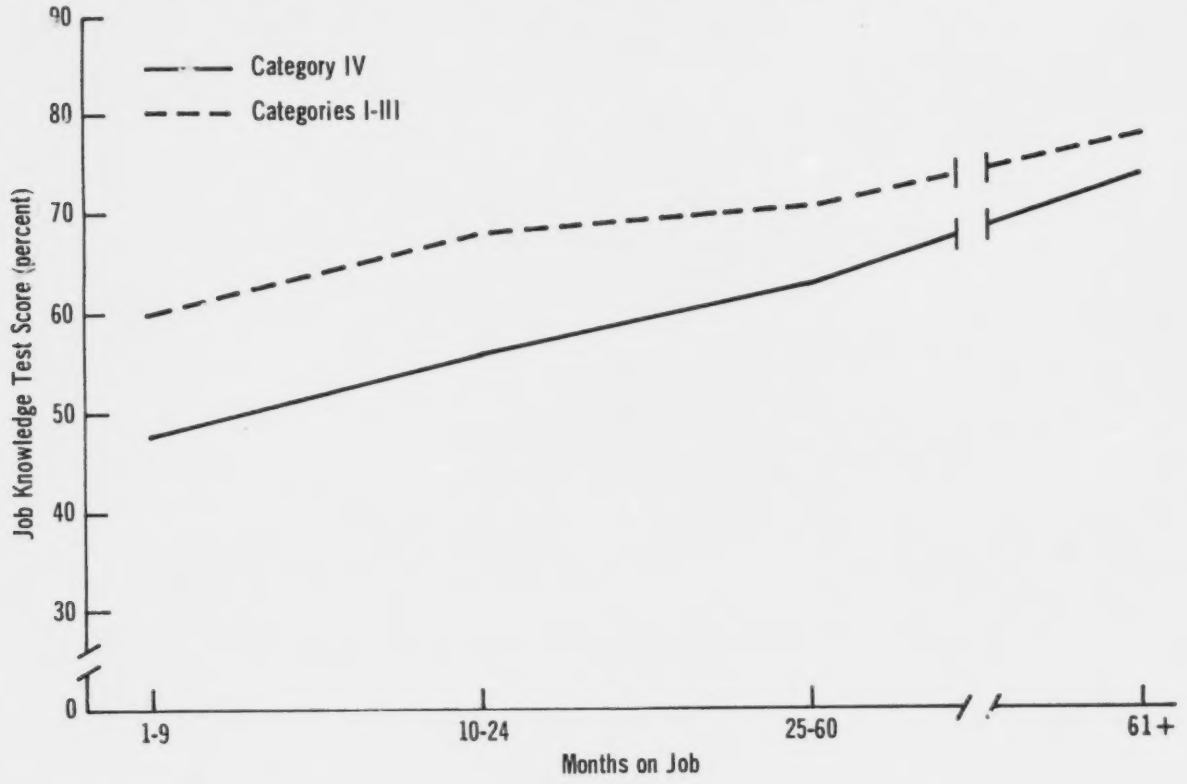

Figure 6

Job Knowledge Test Score by AFQT and Months on Job: Cook

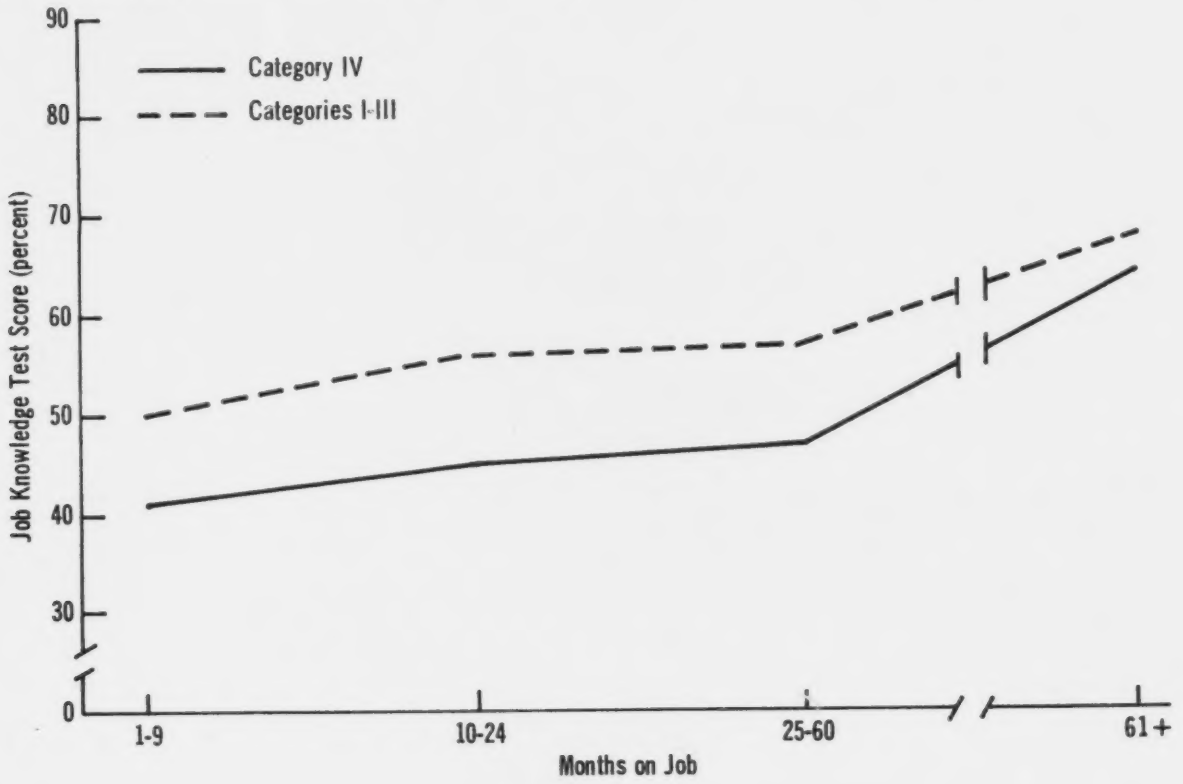

Figure 7

Job Knowledge Test Score by AFQT and Months on Job: Repairman

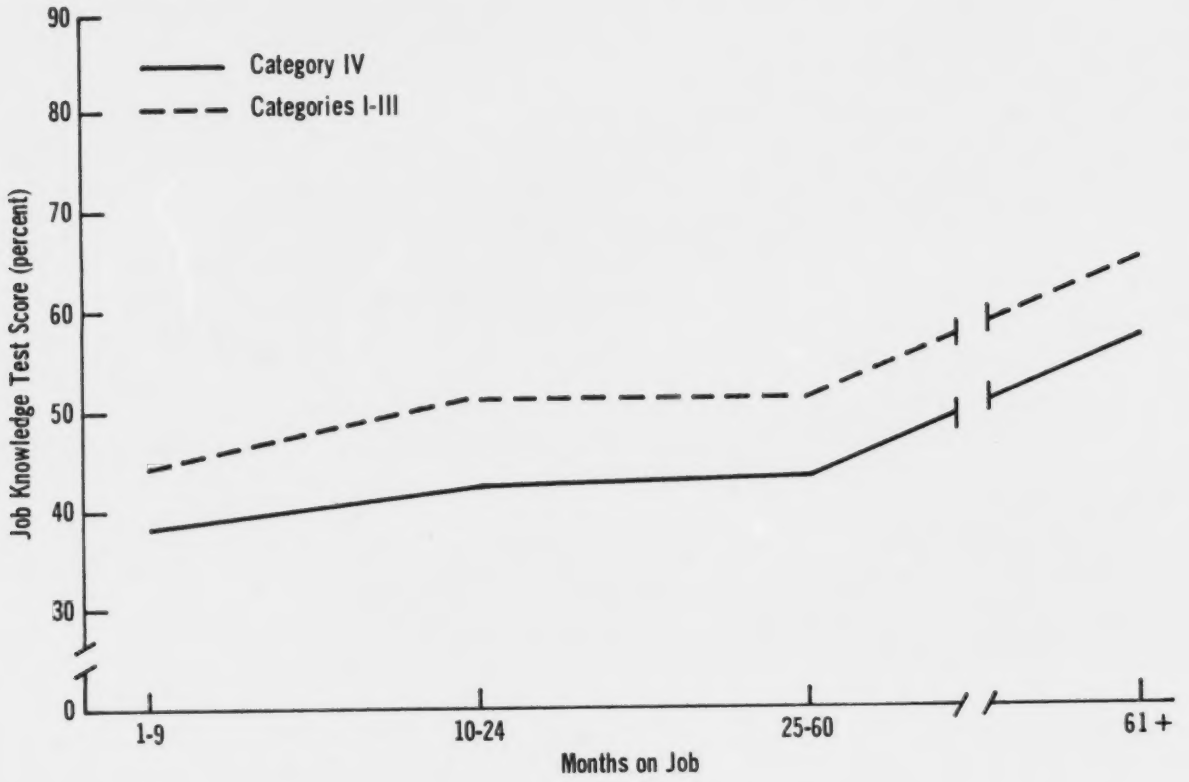

Figure 8

Job Knowledge Test Score by AFQT and Months on Job: Supply Specialist

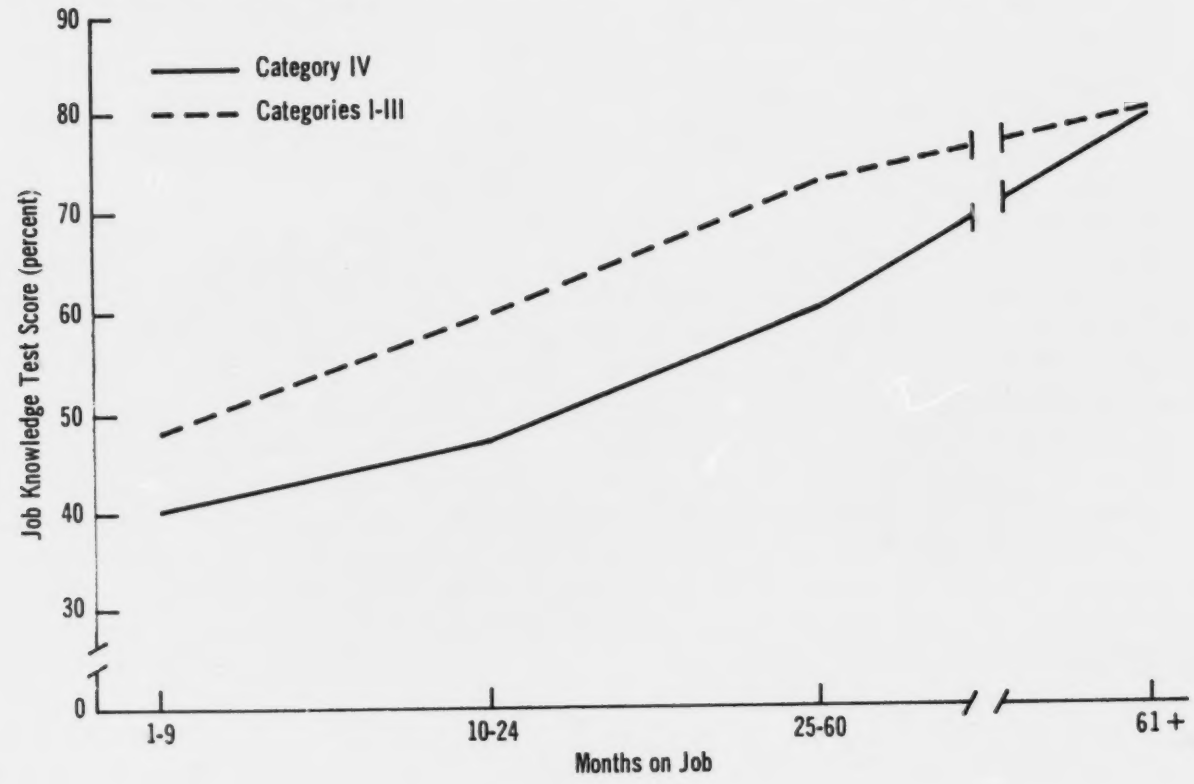

Figure 9

test—a rise of about 30% from the first several months on the job. This point (at 61+ months) in actuality covers a broad span of time. As will be seen later, in theoretical curves that have been generated for predicting job sample scores, the performance of IVs and Non-IVs in this job is expected to converge at about 25 years.

Figure 3 shows that the rate of growth for Cooks is quite gradual. Cooks' performance appears to start at a relatively higher level, probably because recipes were available in cookbooks that all subjects used during testing. On the other hand, men with more than five years' experience are averaging approximately 74% on the test, suggesting that overall this job is more difficult than the Armor Crewman's job.

For Repairmen (Figure 4) there is growth as in the other jobs and evidence of crossover or convergence somewhere after five years where men are averaging about 85% on the test. As will be seen later in the theoretical curves that are extrapolated to 25 years on the job, the Category IVs are expected to perform slightly better than the Non-IVs. This crossover will be discussed with the theoretical curves.

Finally, Supply Clerks (Figure 5) show generally the same trends with subjects eventually averaging 75% on this test. While there is some suggestion of convergence somewhere after five years, the theoretical curves will not bear out this suggestion.

To summarize, during the first nine months on the job, men get about half of the items on the test. Growth occurs at both AFQT levels to at least some position beyond five years on the job where men are getting about three-fourths of the test items and where in some of the jobs there is some evidence of convergence.

As we have stated, we administered more conventional multiple choice tests of job knowledge in addition to the job sample tests. In the next four figures, scores on these tests are plotted for each of the AFQT groups using the same job experience intervals that were used in the earlier graphs.

Here are the results for Armor Crewman (Figure 6). Job knowledge increases rather regularly for both AFQT groups with time. The average score for men beyond five years is about 76%. Growth for Cooks shows (Figure 7) at both AFQT levels with the groups averaging about 66% at the final point. A similar pattern is apparent for Repairmen (Figure 8) with men getting 61% at 61+ months. Finally, for Supply Clerks (Figure 9), considerable growth in job knowledge over time is shown and with the men averaging 75% beyond five years.

The next four figures show scatter plots of individual scores on job sample tests. These plots provide a more detailed picture of the changing pattern of scores across the broad range of job experience and show a considerable overlap of the Category IV and Non-IV distributions.

Although Figure 10 is for Repairman, in general, the scatter plots for the other three jobs (Figures 11, 12, 13) are quite similar. In each MOS there is great variability among men in both the IV and Non-IV mental categories during the first 30 months of job experience. In particular there are both Category IVs, shown by the black triangles, and Non-Category IVs, shown by the open circles, who achieve scores in the upper part of the distribution. The major change during this period is a decrease in the occurrence of low scores. After 30 months, the majority of scores fall within a restricted range at the upper end of the distribution, with a rather clear and stable floor of performance being evident. While these changes presumably reflect the effects of increasing job experience, it must be noted that this pattern may represent some composite of the effects of job experience and of selective reenlistment and reassignment processes. In a cross-sectional study such as this one, it was not possible to isolate the effects of selection.

One of the continuing problems faced in manpower assessment is the establishment of criterion levels of job proficiency that have functional utility. Data of this study provide an opportunity to establish an empirically based, operational definition of job proficiency in terms of performance on work sample tests.

Job Sample Data: Repairman

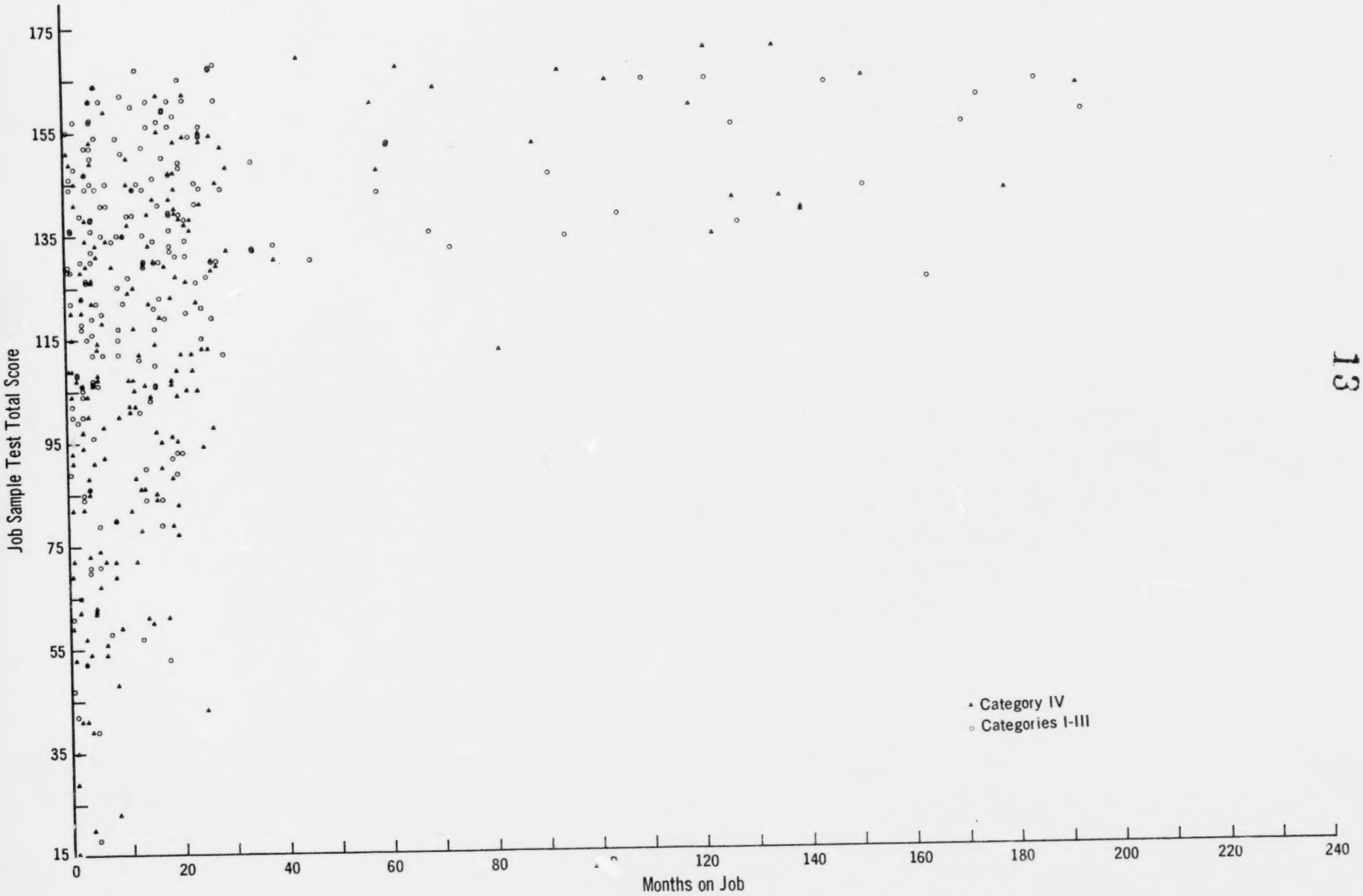

Figure 10

Job Sample Data: Supply Specialist

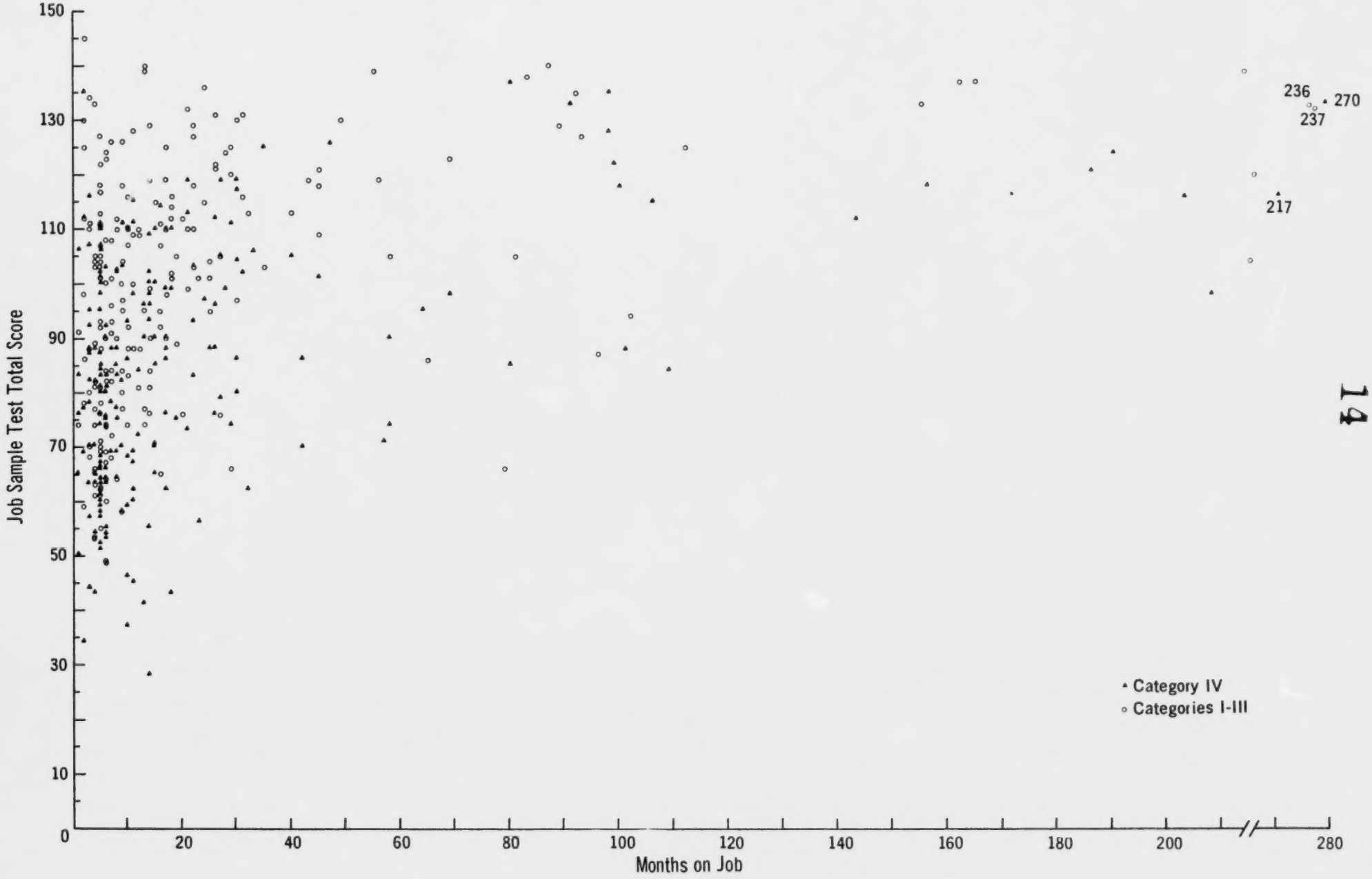

Figure 11

Job Sample Data: Cook

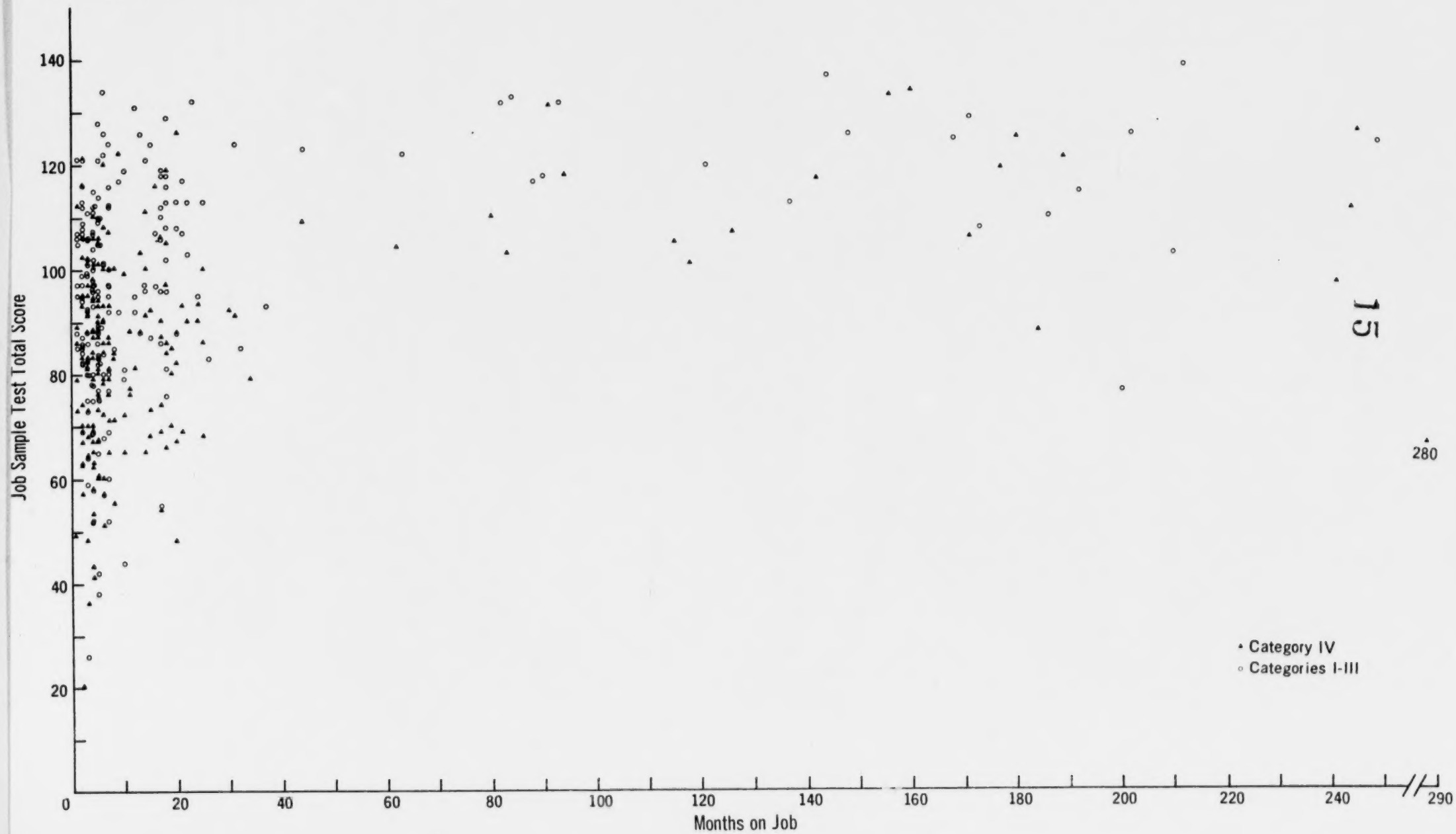

Figure 12

Job Sample Data: Armor Crewman

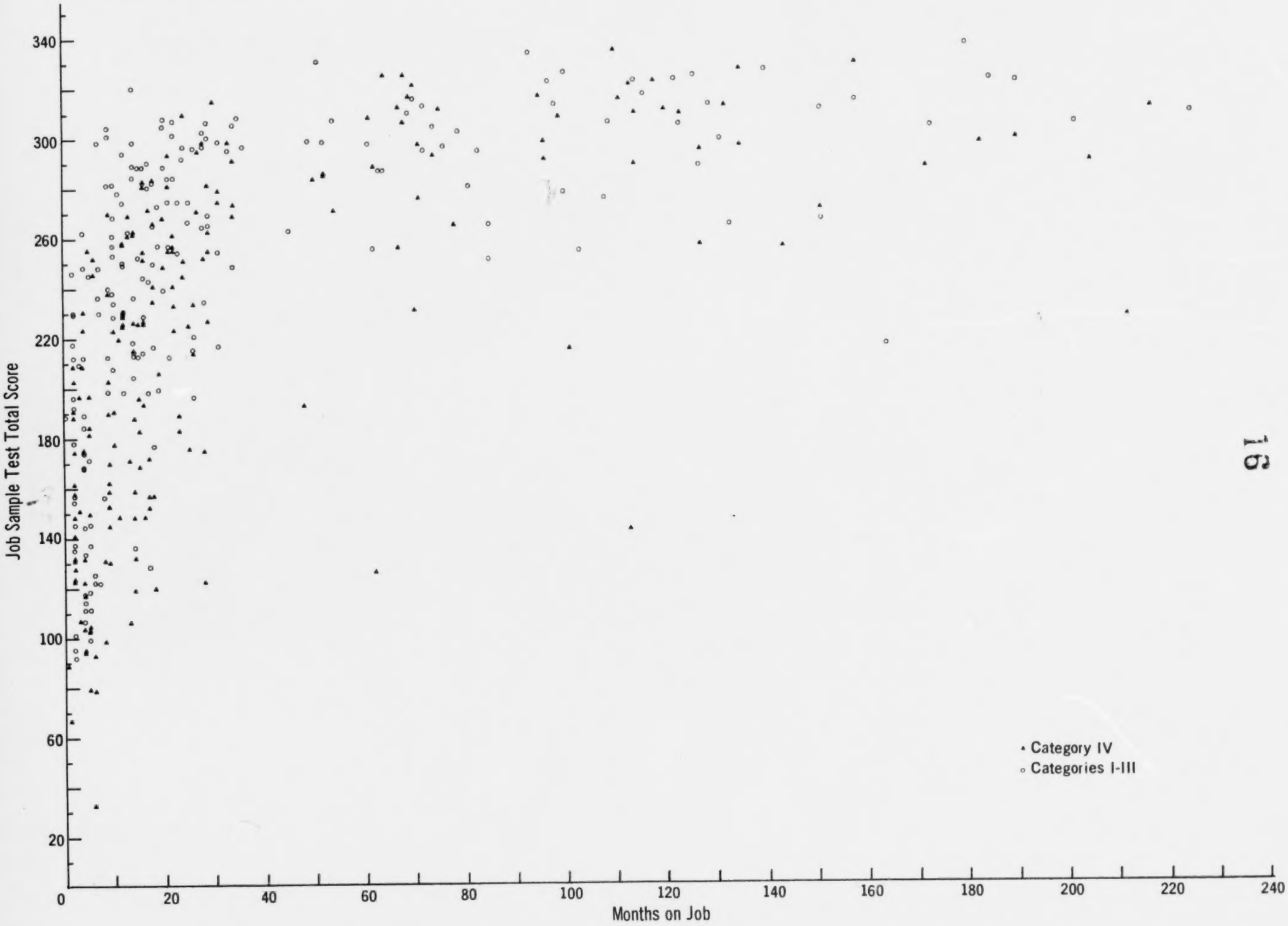

Figure 13

Ideally, minimum satisfactory performance would be defined in terms of specific operational requirements. The present state of human factors technology, however, does not provide performance specifications that are sufficiently precise to allow this ideal to be achieved.

Examination of the scatter plots of job sample data suggests an alternative approach, a relative rather than absolute procedure for defining acceptable performance. In the scatter plot for the Armor Crewman, there is the rather clearly defined floor of performance for men with more than 30 months of job experience. The vast majority of cases cluster in a rather narrow band of performance floor. This band can be considered, in effect, to represent the range of normal and expected performance for experienced job incumbents. It, therefore, appears reasonable to adopt the lower limit of this band beyond 30 months as defining minimal acceptable performance.

For Armor Crewman, minimal acceptable performance defined in this manner is approximately 71% of the points possible on the job sample test. (The comparable minimum levels for the other three jobs are: For Repairman, 75%; Supply Specialist, 54%; and Cook, 56%.) With such a definition, only 5 to 10% of the job incumbents with 30 or more months of experience are seen to fall below minimum performance standards.

We also have some prediction curves to show when Category IVs and Non-IVs can be expected to reach these levels of acceptable performance. To develop the prediction curves we transformed all raw scores to standardized scores (with Mean of 50 and Standard Deviation of 10) and computed the average standardized score for each year. Parameters for a modified exponential equation were obtained for IVs and Non-IVs separately for each job and then for all jobs combined (Figures 14-23).

The analytic expression selected to fit the data is given by the equation

$$\bar{Z}(t) = 80\,(1-\alpha e^{-\beta t})$$

where
- t = time in the job
- $\bar{Z}(t)$ = the standardized score corresponding to the raw score at time t
- α, β = numerical parameters to be estimated from the data for each case (with a case being a specific job, AFQT level, and criterion measure)
- 80 = the value of the asymptote, selected as three standard deviations above the mean, to provide a constant asymptote for all cases.

In deriving our equations the number of observations for each time period was not taken into account; that is, the means for each year are equally weighted. It should be pointed out that as the number of years of job experience increases, fewer men are represented and, therefore, the averages upon which the theoretical curves for individual jobs are based are less reliable. The theoretical curves for combined jobs provide more stable data. However, we show the theoretical regression curves for job sample scores in the four jobs separately. A dotted line representing the suggested minimum acceptable level (taken from each scatter plot of scores beyond 30 months of job experience) has been drawn across each graph.

In this and the rest of the theoretical curves, whether the curves converge appears to be closely related to the difficulty level of the job. As was mentioned, Armor Crewmen (Figure 14) were averaging approximately 82% of the possible points beyond five years on the job. It will be observed that when men average more than three-fourths of the possible points on a test, the curves of the IVs and Non-IVs do converge. It can be noted that the curve for Non-IVs is above minimum acceptability at the outset, whereas the Category IV curve does not reach this level until about five years have elapsed.

For Cooks (Figure 15) who had an average performance of 74% beyond five years, the curves do not converge. Minimal acceptable performance is 49 points in standardized score form and both the IV and the Non-IV curves are above this level at the outset.

Predicted Performance of Category IV and Non-Category IV on Job Sample Test: Armor Crewman (In Relation to a Criterion of Acceptable Performance)

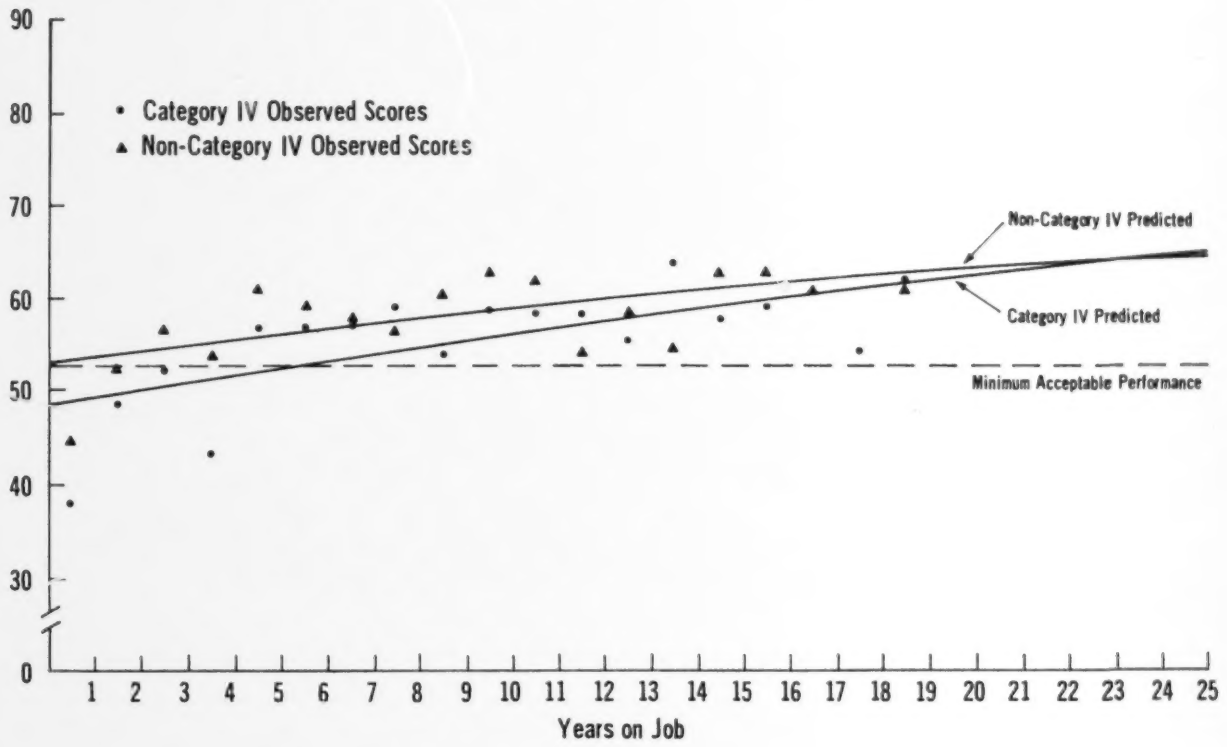

Figure 14

Predicted Performance of Category IV and Non-Category IV on Job Sample Test: Cook (In Relation to a Criterion of Acceptable Performance)

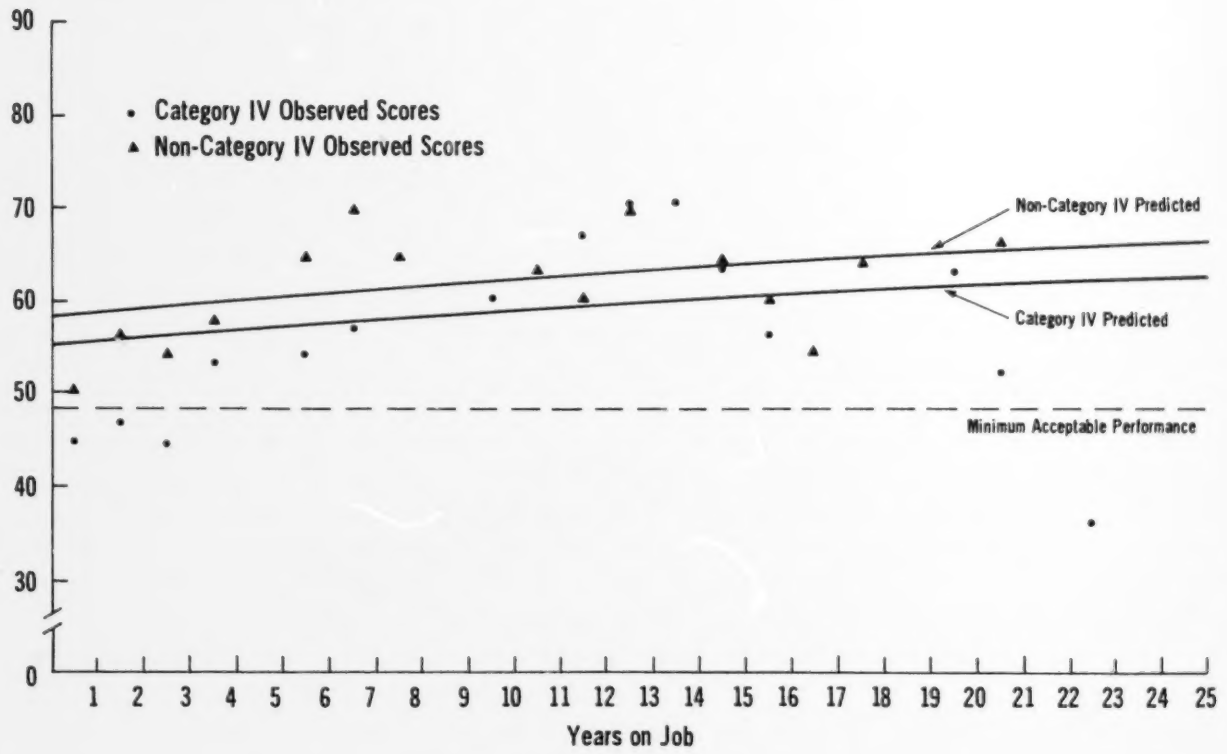

Figure 15

Predicted Performance of Category IV and Non-Category IV on Job Sample Test: Repairman (In Relation to a Criterion of Acceptable Performance)

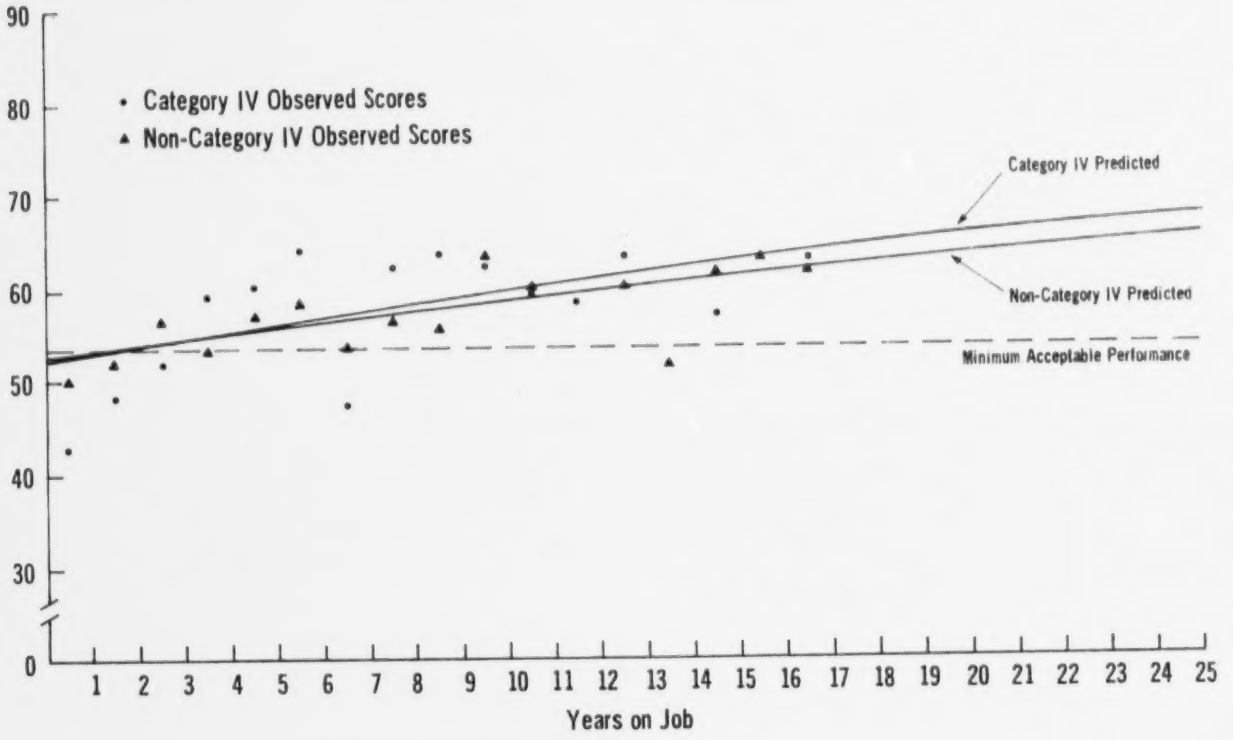

Figure 16

Predicted Performance of Category IV and Non-Category IV on Job Sample Test: Supply Specialist (In Relation to a Criterion of Acceptable Performance)

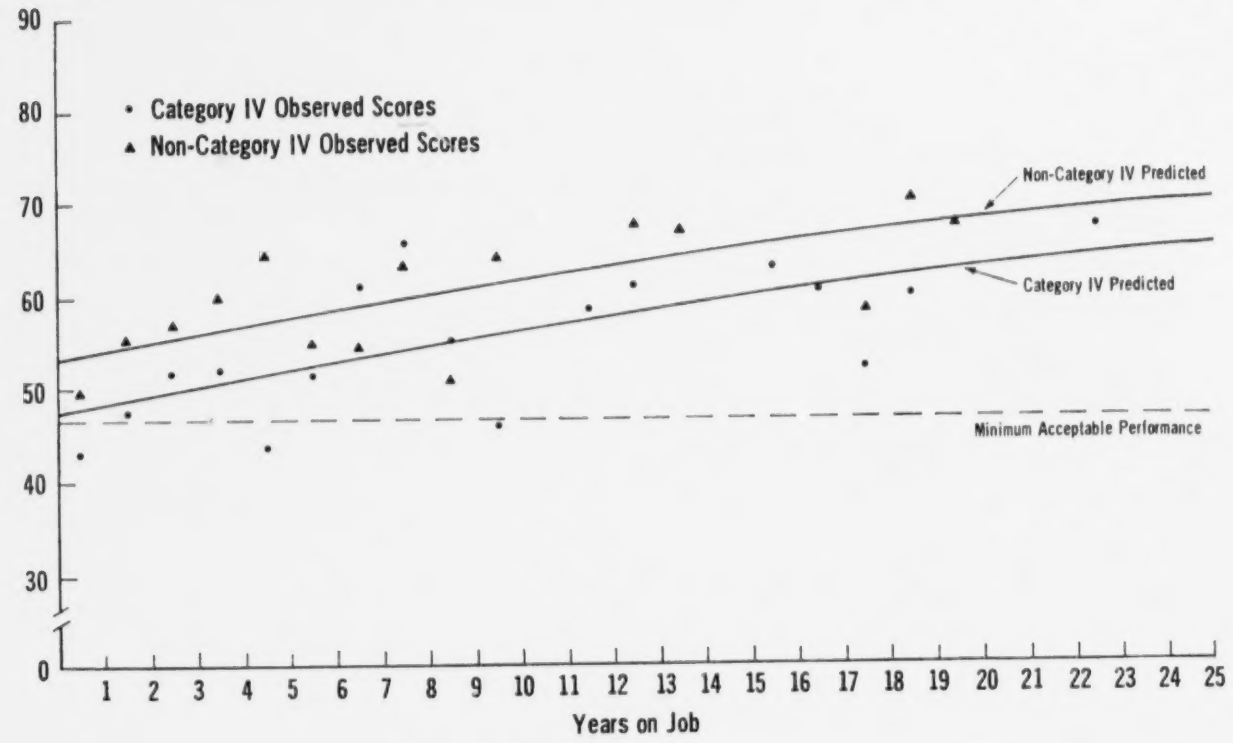

Figure 17

Predicted Performance of Category IV and Non-Category IV on Job Knowledge Test: Supply Specialist

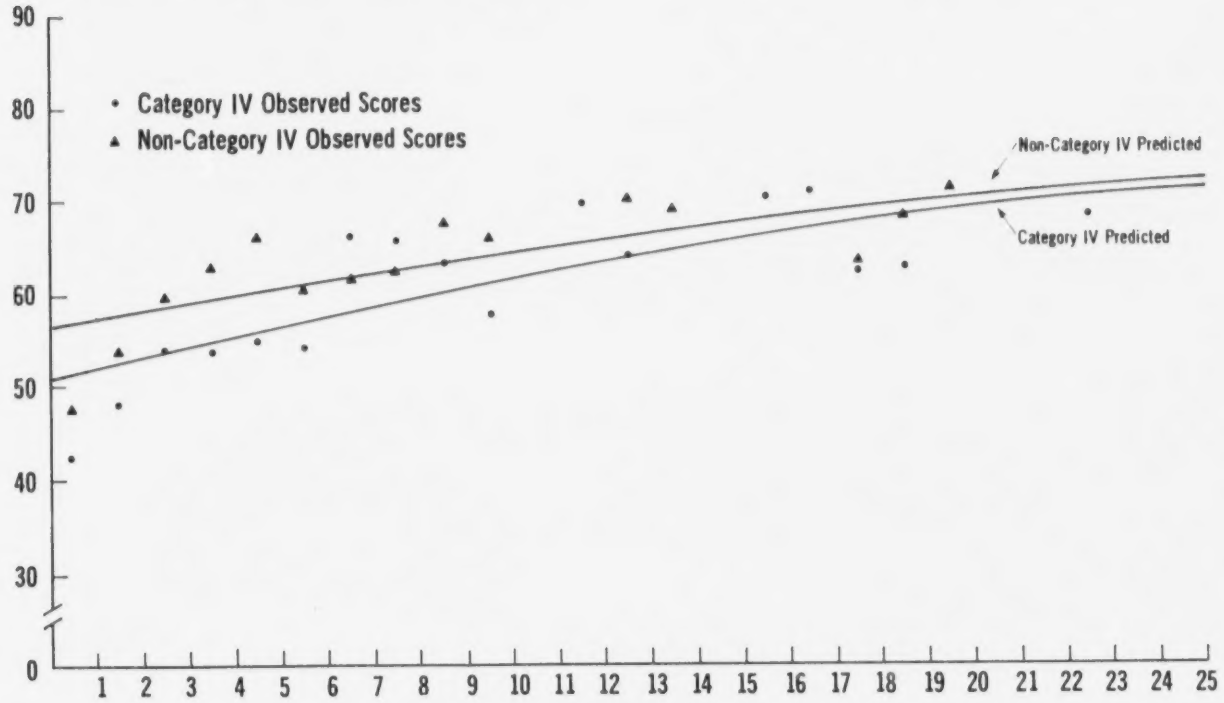

Figure 18

Predicted Performance of Category IV and Non-Category IV on Job Knowledge Test: Armor Crewman

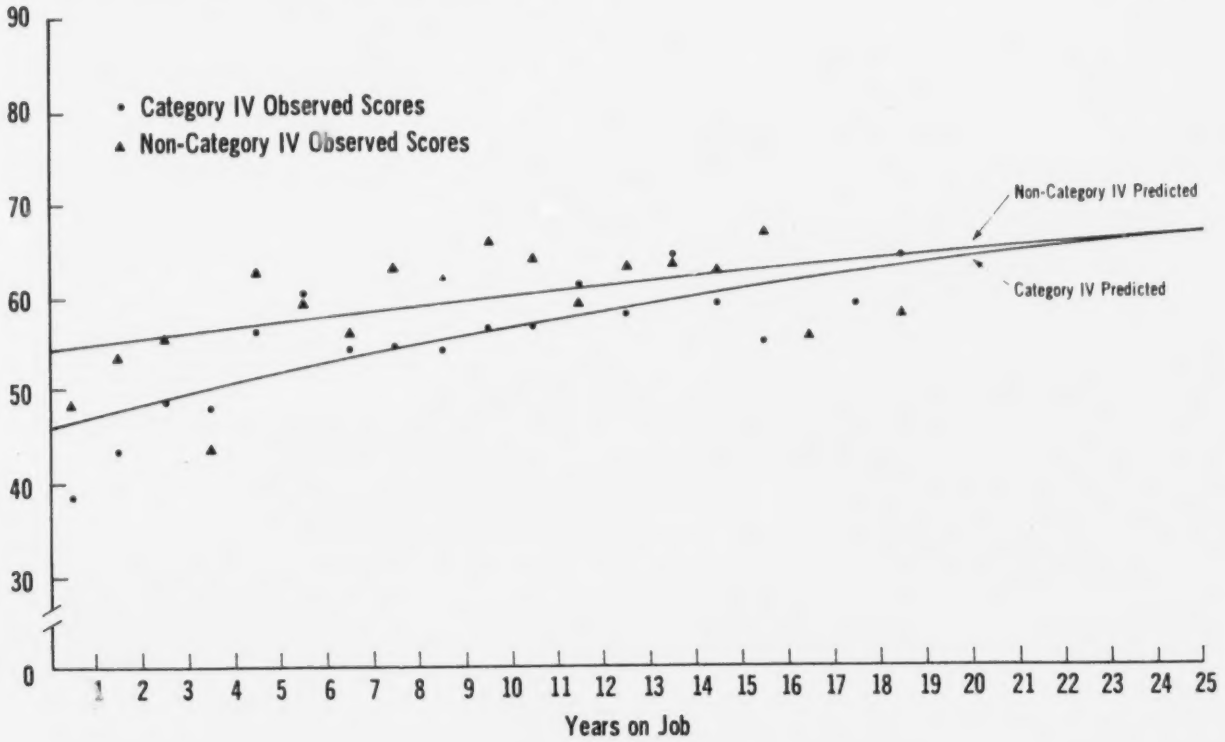

Figure 19

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Predicted Performance of Category IV and Non-Category IV on Job Knowledge Test: Cook

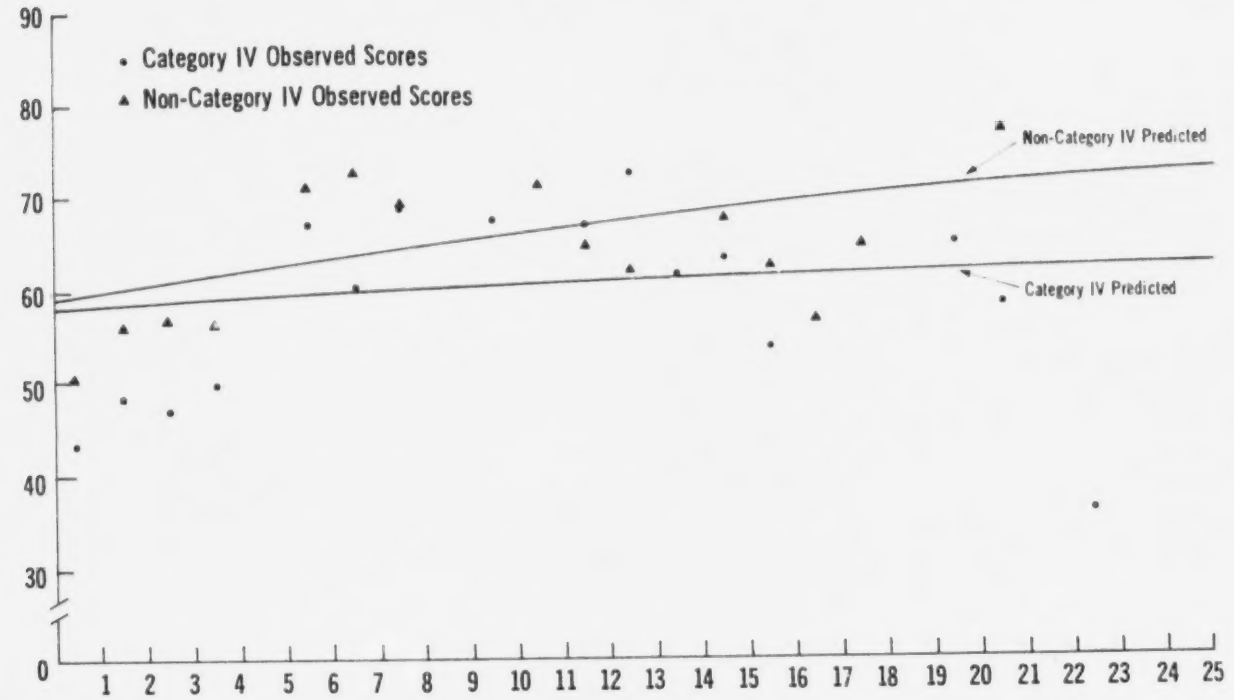

Figure 20

Predicted Performance of Category IV and Non-Category IV on Job Knowledge Test: Repairman

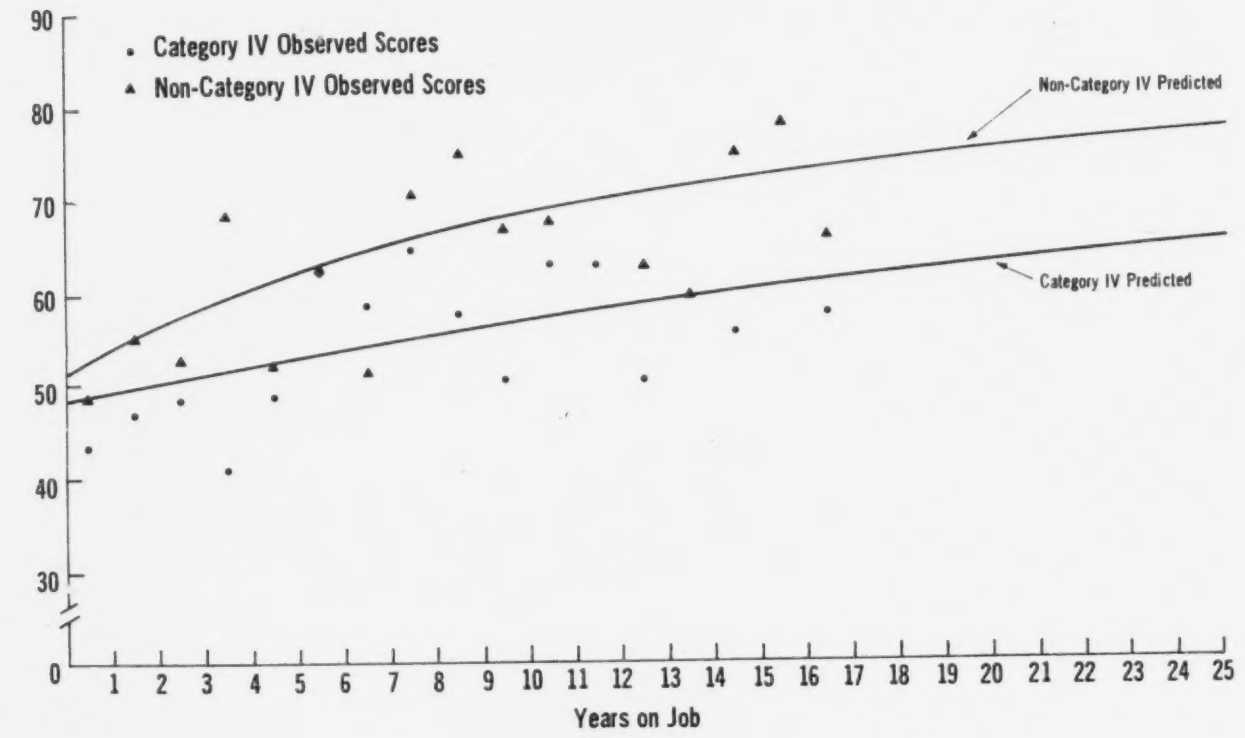

Figure 21

Predicted Performance of Category IV and Non-Category IV on Job Sample Test: Four MOSs Combined

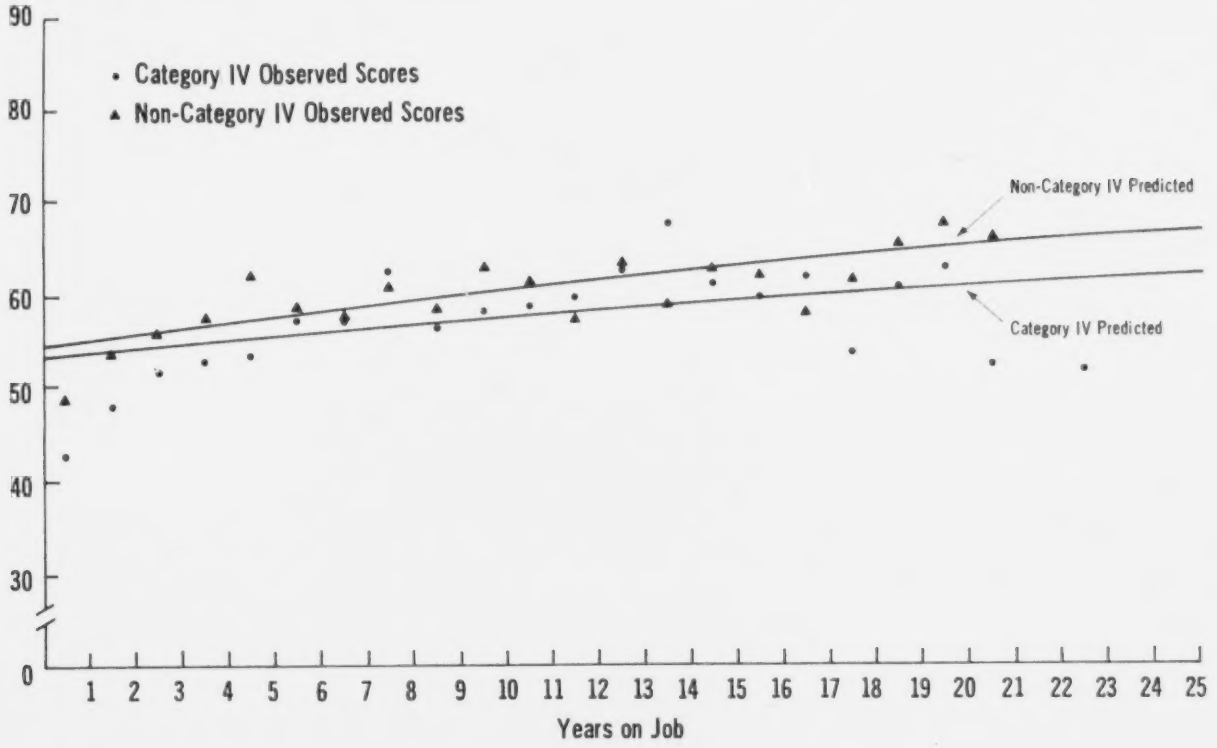

Figure 22

Predicted Performance of Category IV and Non-Category IV on Job Knowledge Test: Four MOSs Combined

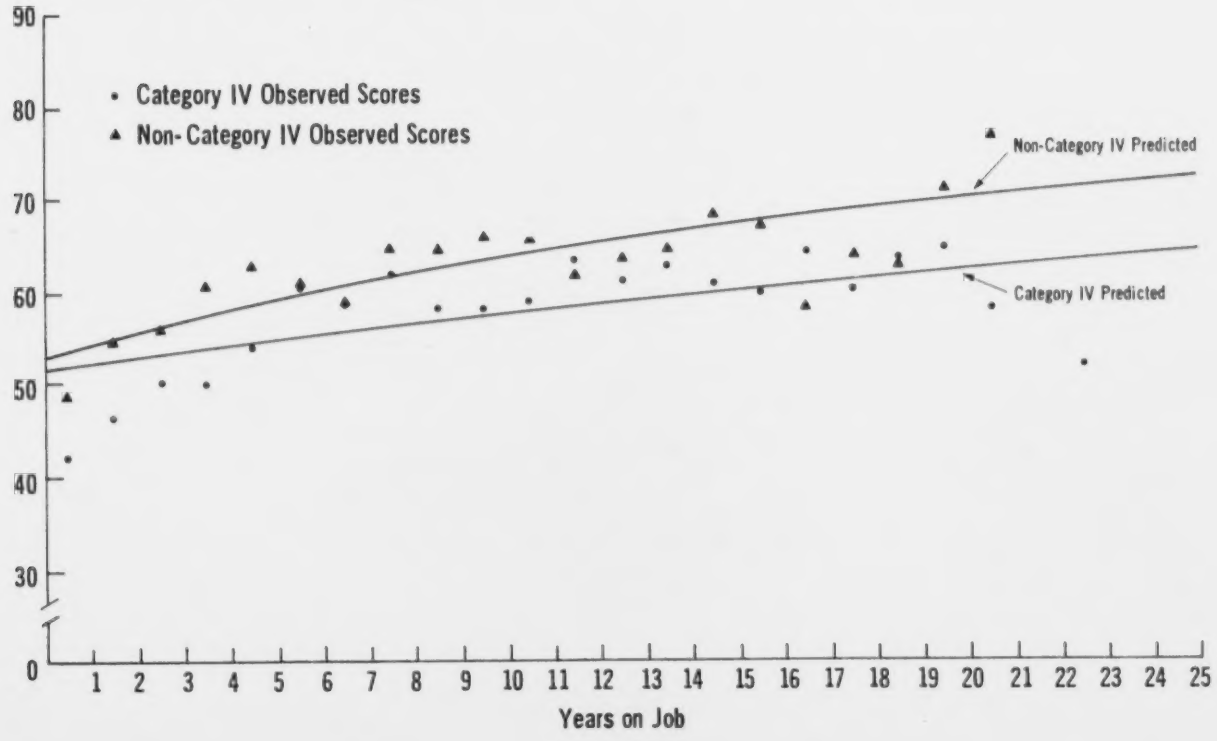

Figure 23

22

For Repairmen (Figure 16), where men average better than 75% after two years on the job, the curves in effect coincide for the first seven years and thereafter diverge with the curve for the IVs being slightly higher. This is the only job where this kind of inversion will be observed. Perhaps we should not attach a great significance to this crossover since in this particular job the number of men who had more than five years was considerably less than in the other specialties studied. According to the line of minimum acceptable performance, both the IVs and Non-IVs would be expected to attain minimum acceptability after approximately 17 months on the job.

For Supply (Figure 17), where men with more than five years' experience averaged exactly 75% on the test, the curves do not converge. Minimum acceptable performance is 47 (in standard score form) and both the IV and Non-IV curves are above this point at the beginning.

We did not establish minimum levels of acceptability for this more intermediate criterion of job knowledge curves. The theoretical curves of job knowledge are consistent with the job sample curves in that convergence occurs only where groups average better than 75%. In Supply (Figure 18), men averaged 80% beyond five years and the curves are approaching convergence.

In Armor Crewman (Figure 19), men averaged 76% beyond five years and the curves converge. In Cooks (Figure 20), where men were averaging 66% beyond five years, the curves are quite divergent. For Repairmen (Figure 21), men were averaging only 61% at more than five years on the job, and the curves show the greatest divergence.

Finally, we will consider the theoretical curves for all job combined (Figure 22). As indicated earlier, the pooling of the data from the different jobs provides the most stable estimate of growth in job proficiency of high and low aptitude men. The Non-IV curve is based upon 800 men, as is the Category IV curve. On the job sample curves, there is a better overall fit of the curves to the data. In this combination of the four jobs, the expectancy is that Non-IVs will continue to do better than IVs. The job knowledge curves (Figure 23) show the same improved fit of data. In the job knowledge tests which, in general, were more difficult than job sample tests, there is greater separation of the two AFQT groups.

These theoretical curves represent one example of many possible ways of fitting curves to the data. Several limitations governed the choice of the mathematical functions that could be considered in the curve fitting—(a) Simple analytic expressions were chosen to avoid computational difficulties; (b) a single equation was used, with two varying parameters, to fit all 16 cases (four jobs, two AFQT levels, and two criteria); (c) the same asymptote was adopted for all 16 cases; (d) finally, as already stated, the curves were fitted for the average score observed for each year of job performance.

SUMMARY

In summary, we believe that the two most important points from the study are: First, in several different kinds of jobs both IVs and Non-IVs show job growth with the Non-IVs performing somewhat better. While the differences between Mental Groups tend to remain for a considerable length of time, such differences are probably not critical since both Category IVs and Non-IVs perform satisfactorily relatively early in their job careers.

Second, we have shown that when job sample data are available, reasonable, and, we think, rather compelling, definitions of acceptable performance emerge.[1]

Data of this sort collected for a much larger variety of jobs are desirable. With such data for Category IVs and Non-IVs different patterns of growth associated with specific job families might be identified. Such information would be of obvious advantage to military planners.

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[1] Further information from this research effort is available in these publications:

Robert Vineberg, Thomas G. Sticht, Elaine N. Taylor, and John S. Caylor, *Effects of Aptitude (AFQT), Job Experience, and Literacy on Job Performance: Summary of HumRRO Work Units UTILITY and REALISTIC*, HumRRO Technical Report 71-1, February 1971.

Robert Vineberg, Elaine N. Taylor, and John S. Caylor, *Performance in Five Army Jobs by Men at Different Aptitude (AFQT) Levels: 1. Purpose and Design of Study*, HumRRO Technical Report 70-18, November 1970.

Robert Vineberg, Elaine N. Taylor, and Thomas G. Sticht, *Performance in Five Army Jobs by Men at Different Aptitude (AFQT) Levels: 2. Development and Description of Instruments*, HumRRO Technical Report 70-20, November 1970.

Robert Vineberg and Elaine N. Taylor, *Performance in Four Jobs: The Role of Mental Ability and Experience*, HumRRO Professional Paper 31-70, December 1970.

Robert Vineberg, Elaine Taylor, and John S. Caylor, *Progress Report on Work Unit UTILITY*, HumRRO Professional Paper 6-70, March 1970.